DESCRIPTION INSTALLATION MAINTENANCE

INSTRUCTIONS

HEAVY - DUTY

STEEL MILL
MAGNETIC CONTROLLERS

CLASS 2240

(FORMERLY CLASS 9500)

MILL AUXILIARY SERVICE
CONSTANT VOLTAGE D-C

WESTINGHOUSE ELECTRIC CORPORATION
BUFFALO PLANT INDUSTRIAL SYSTEMS DIVISION BUFFALO, N. Y. 14240

Effective April 1972

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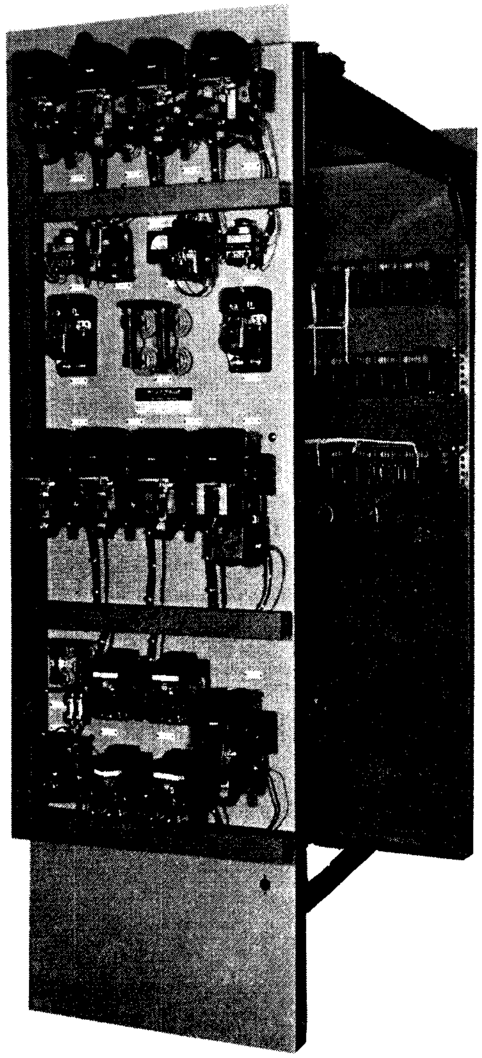


Special Class 2240 Controller Mounted on Bolted Self-Supporting, Factory-Assembled Frame with Starting Resistors Mounted and Wired (Class A Construction with 92-inch High Steel Panel)

Class 2240 (formerly Class 9500) is the general designation given to constant voltage, direct-current, magnetic controllers for use in mill auxiliary service in steel mill and other heavy mill applications.

The specific classes in this general classification are:

Class 2241 (formerly Class 9505) - Non-Reversing Controller
Class 2242 (formerly Class 9510) - Non-Reversing, Dynamic Braking Controller
Class 2243 (formerly Class 9515) - Reversing, Plugging Controller
Class 2244 (formerly Class 9530) - Reversing, Dynamic Braking Controller
Class 2245 (formerly Class 9535) - Reversing, Plugging, Dynamic Braking Controller

These controllers are used for such applications as pushers, tables, screwdowns, sideguard adjustment, etc. They conform to NEMA standards for d-c magnetic control for steel mill auxiliaries.

Part One

GENERAL DESCRIPTION

A complete motor controller includes a control panel, armature circuit resistors, a pushbutton or master switch and where required, limit switches and a field rheostat. The equipment included on the control panel is listed under "Class 2240" component devices and functions" below.

All contactors and relays are assembled as complete units to assure correct alignment of parts.

The arrangement of apparatus is such that controllers of the same ratings or various ratings may be installed in groups and line-up to present a symmetrical and pleasing appearance.

Overload protection is provided by two thermal magnetic relays which provide inverse time limit protection to normal loads, and instantaneous trip on abormal loads of approximately 400 percent. This trip reset botton may be set for "Automatic Reset" or "Manual Reset".

Low voltage protection is provided by a relay which prevents motor from restarting automatically upon the return of voltage.

Acceleration is controlled by definite time limit relays which are pneumatic with time calibrated dial heads which may be easily adjusted for the exact time setting that best fits the operating schedule.

Separate knife switches are provided for the motor armature circuit and the control circuits so that the control may be tested without energizing the motor. Both main and control knife switches are each provided with locking clips for up to three padlocks at the same time.

CLASS 2240 COMPONENT DEVICES AND FUNCTIONS

The devices listed in "Paragraph A" are required for all standard class 2240 controllers. For detailed information on specific controllers, such as the number of accelerating contactors, contactor size etc. etc. refer to price list 22-420, price modification 22-421 and application data 22-440.

Each specific class in this general classification requires additional devices to complete the controller. These devices for constant speed compound motors (Class 2241 and 2243 may also be used with series motors) are listed in "Paragraphs B to F", plus the necessary resistors and interlocks.

Paragraph A. All Class 2240 Controllers require the following:

Quantity	Function and Device	Device Marking
1	Negative Line Contactor	1M
2	Accelerating Contactor	1A, 2A
2	Overload Relays	1OL, 2OL
2	Definite Time Accelerating Relays	1TR, 2TR
1	Master Relay	MR
1	Motor Line Knife Switch with Locking Clip and 90-degree Stop	
1	Control Knife Switch	
2	Control Fuses	

Note: In addition to the above, shunts and/or ammeters may be furnished for any controller as optional additions.

Class 2240 controllers have been designed with a 50 mv shunt rated at 125 to 150 percent of the motor full load current and a 100 mv ammeter with a full scale of 250 to 300 percent full load. The selection of these values permits the reading of starting peaks and other momentary surges. This also allows recording type ammeters or other meters having 100 mv movement to be used.

Paragraph B. Class 2241 (Non-Reversing) Controllers require the following device in addition to those listed in Paragraph A:

Quantity	Function and Device	Device Marking
1	Positive Line Contactor	2M

Paragraph C. Class 2242 (Non-Reversing, Dynamic Braking) Controllers require the following devices in addition to those listed in Paragraph A:

Quantity	Function and Device	Device Marking
1	Positive Line Contactor	2M
1	Dynamic Braking Contactor	DB

Paragraph D. Class 2243 (Reversing, Plugging) Controllers require the following devices in addition to those listed in Paragraph A:

Quantity	Function and Device	Device Marking
4	Armature Reversing Contactors	1F, 2F (Forward)
1	Plugging Contactor	P
1	Plugging Relay	PR

Paragraph E. Class 2244 (Reversing, Dynamic Braking) Controllers require the following devices in addition to those listed in Paragraph A:

Quantity	Function and Device	Device Marking
4	Armature Reversing Contactors	1F, 2F (Forward) 1R, 2R (Reverse)
1	Dynamic Braking Contactor	DB
1	Anti-Plugging Relay	AP

Paragraph F. Class 2245 (Reversing, Plugging, Dyanamic Braking) Controllers require the following devices in addition to those listed in Paragraph A:

Quantity	Function and Device	Device Marking
4	Armature Reversing Contactors	1F, 2F (Forward) 1R, 2R (Reverse)
1	Plugging Contactor	P
1	Dynamic Braking Contactor	DB
1	Plugging Relay	PR
1	Timing Relay	3TR

Paragraph G. Armature shunt may be added to Class 2242, 2244 or 2245 controllers without any additional devices by employing the dynamic braking contactor DB and the dynamic braking resistor for this as well as their normal function. Where separate armature shunt contactor is required, or on Class 2241 or 2243 which do not have dynamic braking; the following additional devices are required:

Quantity	Function and Device	Device Marking
1	Armature Shunt Contactor	AS
1	Armature Shunt Relay	AR
1	Armature Shunt Resistor +	

\+ Part of dynamic braking resistor on Class 2242, 2244 or 2245.

Paragraph H.

Field Relays. In most cases, a dual coil relay with adjustable pick-up and drop-out is used for field relay applications.

FL-Field Loss. Not required on series motors or mill type compound motors having less than 60 percent shunt field (note: Westinghouse mill type compound motors have less than 60 percent shunt field). Required on straight or stabilized shunt motors or mill type compound motors having 60 percent or more shunt field.

FP-Field Protective (or Field Economizer). Required on all motors whose shunt field is not continuously rated when the motor is at stand-still with full field. Not required on Westinghouse mill type motors either shunt or compound.

FA-Field Acceleration.Ø Required on all adjustable speed motors of over two to one speed range if the field setting can be rapidly changed from "Slow" to "Fast".

FD-Field Deceleration.Ø Required on all adjustable speed motors at over two to one speed range if the field setting can be rapidly changed from "Fast" to "Slow".

Ø FA and FD Relays may be required on adjustable speed motors two to one or less speed range if connected to high inertia load.

Paragraph I.

Control Relays. In addition to the relays which are required for the various classes of controllers as listed in Paragraphs A to H above, relays of various kinds are required for dual or triple control of one motor, duplex operation of two motors, or for any of the many other special applications.

CONSTRUCTION

The devices for any given controller, as itemized in the preceding paragraphs, are mounted on steel panels, which are mounted on a fabricated steel frame, or mounted in an enclosure.

The arrangement of the apparatus is such that the controllers may be installed in groups and lineup to present a symmetrical and pleasing appearance.

The types and classes of construction are as follows: (Also see Fig. 1 illustration in Part 3)

Class A. Self-supporting factory assembled frames with full height panels 92 inch high panels are standard,for other heights consult factory) interconnecting main and control buses; main and control terminal boards; and all resistors mounted and wired.

A standard frame arrangement is shown in Fig. 1A and also in frontispiece, page 3, "Unit Frame" construction is used such that each controller panel, the resistors, and the supporting frame is a complete self supporting unit in itself. This construction besides giving a sturdier installation permits greater flexibility, Controllers are bolted together and may be rearranged easily or separated and moved to new locations if mill layout is changed. The frame may be mounted with the resistor rack against the wall as the resistors are mounted and wired so that they can be removed from the "aisle" side of the resistor rack.

Controllers are usually shipped in sections consisting of several panels bolted together with a common main bus. Bus links are provided to interconnect the bus to the adjoining section.

If desired two frames may be connected "back to back" as shown in Fig. 1B.

<u>Class B.</u> Fig. 1 (c), includes all features of Class A construction except line, starting and/or dynamic braking resistors are shipped separately for mounting and wiring by the purchaser. Panels must be supported by wall or floor braces and are usually shipped in sections with a common main bus.

<u>Class C.</u> Fig. 1 (d), is similar to Class B, except main bus is omitted in addition to resistors being supplied separately, unmounted and unwired. Panels are usually shipped individually.

<u>Class D.</u> Fig. 1 (e), is the least class of construction but requires the most installation. The panel must be supported, armature circuit resistors mounted and wired and if there is more than one panel a bus must be provided and wired to each panel. Since no terminal board is provided for motor armature connections, the cables must be left long enough to reach directly to the contactor studs. Class D controlled panels are shipped individually.

In addition to the standard Classes of construction listed above, variations are available where space is a problem or there is other special customer requirements. These variations include panels of the heights and controllers which are front accessible only.

<u>Enclosures.</u>

Any Class 2240 control panel can be mounted in any of the various NEMA types of enclosures. The most common being NEMA type 1 (General Purpose) both with and without gaskets. NEMA type 12 (Dusttight) is also frequently employed.

Armature circuit resistors (starting, dynamic braking etc.), when mounted and wired, are in a ventilated enclosure; usually mounted on top of the control enclosure.

Figure 1 (f) illustrates a typical enclosed controller.

RATINGS

Controllers are rated in accordance with NEMA steel mill standards and should be used with a d-c motor of the voltage and horsepower rating stamped on the controller nameplate.

NEMA resistor classifications are listed in Table No. 1 below. The operating time of the starting resistors should not exceed the values given in this table for the Class of resistor as indicated on the resistor diagram.

TABLE NO. 1 NEMA RESISTOR CLASSIFICATIONS

Percent Full Load Current On First Point	* Starting Torque % Of Full Load			RESISTOR CLASS NUMBERS - DUTY CYCLE						
	Series Motors	Compound Motors	Shunt Motors	5 Sec on Out of 80 Sec.	10 Sec on Out of 80 Sec.	15 Sec on Out of 90 Sec.	15 Sec on Out of 60 Sec.	15 Sec on Out of 45 Sec.	15 Sec on Out of 30 Sec.	Continuous (Not Necessarily At Full Load)
25	8	12	25	111	131	141	151	161	171	91
50	30	40	50	112	132	142	152	162	172	92
70	50	60	70	113	133	143	153	163	173	93
100	100	100	100	114	134	144	154	164	174	94
150	170	160	150	115	135	145	155	165	175	95
200	250	230	200	116	136	146	156	156	176	96

* Based on Westinghouse motors.

Part Two

DESCRIPTION OF CIRCUITS

Class 2241 Non-Reversing Controller (NR)

A Class 2241 scheme is shown in Fig. 2 Page 15. Points "P", "O", RST", etc. are logic input points for controlling the basic controller. Pushbuttons are used as the logic but, a master switch, relay contacts, limit switches may be used instead.

With the main and control knife switches closed, timing relays 1TR and 2TR are energized, and momentarilly pressing the "START" button energizes the master relay (MR).

The main contact of MR closes energizing the line contactors 1M and 2M which connect the motor armature and the starting resistor in series across the line. An interlock of 2M de-energizes the accelerating timer 1TR. The accelerating contactors 1A and 2A are de-energized so the starting resistor limits the current to some value (frequently 150 percent of full load) above the break away load torque of the motor.

The motor starts to rotate and as the speed increases the armature counter voltage (EMF) builds up and the current decreases.

When 1TR times out, contactor 1A closes to short out part of the starting resistor which increases the current again to continue the acceleration. An interlock of 1A de-energizes timer 2TR and when it times out, 2A shorts the remaining resistance and the motor. accelerates to "base speed".

Timers 1TR and 2TR are usually adjusted to give equal current peaks.

Pressing the "STOP" button de-energizes MR relay which stops the motor. If one of the overload relay contacts(or a contact of another protective device) opens in the MR coil circuit, or in the case of low voltage, relay MR is de-energized and the controller will not operate until the abnormal condition is remedied, and the protective devices reset (if they have opened) and the "START" button once again depressed.

Fig. 2A Page 15 shows the speed-torque characteristics of a compound wound motor with a Class 2241 controller.

Class 2242 Non-Reversing, Dynamic Braking Controller (NRDB)

A class 2242 scheme is shown in Fig. 3 page 16 . This similar to the class 2241 basic controller scheme described previously except that dynamic braking has been added. A master switch is used for thelogic but pushbuttons or other devices could be used instead.

The master switch, in this case, permits three different speeds to be selected by the operator. In any of the speed points, the line contactors are picked up as in the Class 2241 and the dynamic braking contactor energized to open its contact. The dynamic braking contactor and resistor may also be employed as an armature shunt speed point (Refer to Page 11 and Fig. 8 Page 21)

If the master switch is moved to second position, the first accelerating contactor is energized if or when the timer 1TR has timed out and the motor speed will be on curve "b" not "a" as on the first point as shown on Fig. 3A.

Master switch being moved to the third point will cause 2A to be energized, again if or when 2TR times out thus being on curve C.

If the master switch is moved to the "OFF" position or MR is de-energized by any overload or other contact; all the contactors will drop out including DB whose normally closed contact will connect the dynamic braking resistor across the armature to brake the motor to a halt as shown by curve d.

Because the DB contactor is a spring closed contactor, emergency dynamic braking is still available if control power is lost or an overload or other protective device operator.

Class 2243 Reversing, Plugging Controller (RP)

A Class 2243 circuit is shown in Fig. 4, Page 17. When the master switch is moved to a "Forward" position, contactors 1M, 1F, and 2F connect the armature to the power circuit. When the master switch is moved to a "Reverse" position, contactors 1M, 1R, and 2R connect the armature to the power circuit, the armature polarity is now reversed with respect to the polarities of the shunt field and series field and the direction of rotation is reversed.

Contactor 1F and 2R are mechanically interlocked so that it is impossible to close both simultaneously. Likewise contactors 2F and 1R are mechanically interlocked.

The functions of contactors 1M, 1A, 2A and relays 1OL, 2OL, Mr, 1TR, 2TR are the same as their function in the Class 2241 circuit. The coil of relay 1TR is de-energized by the opening of contactor interlock P rather than by the opening of interlock 2M.

A d-c motor is plugged by reversing the polarity of the voltage applied to the armature of the motor while in motion. In this manner, power from the line can be utilized to decelerate and stop the motor. It will then accelerate in the reverse direction in the normal manner. This operation makes it possible to reverse the direction of rotation in a minimum of time. All steps of the starting resistor as well as an additional step knowmas the plugging resistor are inserted into the armature circuit to limit the armature current when the motor is plugged.

The plugging is controlled by plugging relay "PR". When the motor is started from rest, the diode in series with the coils of PR prevents the relay from being picked-up. The normally closed contact of PR allows the plugging contactor "P" to be energized at the same time as 1M and since the plugging section of the starting resistor R1-R2-is shorted out the motor accelerates in the same manner as described previously for Class 2241 and Class 2242 controllers.

If the operating in one direction (forward for example) the master switch is moved to the opposite position (reverse in this case), the forward contactors 1F and 2F will open and the reverse contactors 1R and 2R will close.

The counter EMF of the motor is now in series with the line voltage and since the polarity of the armature with respect to the PR relay coil and its diode is now the same. The relay will pick-up. This in turn drops out the contactor P to insert resistor R1-R2 which limits the plugging current to a safe value consistant with higher voltage due to the addition of the counter EMF to the line voltage.

As the motor slows due to braking torque the counter EMF reduces until at a low value (approaching zero speed) relay PR drops out. Contactor P recloses and the motor passes through zero speed and accelerates in the now reverse direction in the same manner as described before.

Fig. 4A Page 17 shows the speed torque characteristic of a compount motor with a class 2243 controller. Curves below the torque axis are for reverse rotation.

Class 2244 Reversing, Dynamic Braking Controller (RDB)

A Class 2244 elementary circuit diagram is shown in Fig. 5 Page 17. The functions of all the devices are the same, as in the Class 2243 circuit with the exception of the dynamic braking contactor DB, and the anti-plugging relay AP. Dynamic braking operates in the same fashion as in Class 2242 controllers.

When the armature is rotating at full speed in one direction, and the master switch is moved rapidly to the opposite position, relay AP insures that the armature will nearly stop, before the contactors close the armature circuit for the opposite direction of rotation. AP is a voltage sensitive relay, set to drop out at a low voltage. The anti-plugging relay AP only functions when the direction of rotation is reversed. The controller may be jogged repeatedly in the same direction without waiting for the motor to slow down.

Fig. 5 (a) shows the speed torque characteristic if the master switch is placed in the third point forward when the motor is at rest. Motor will accelerate to full speed forward. The master switch is then reversed and the motor dynamic brakes almost to zero, then plugs to zero and accelerates to full speed in reverse. The master switch is then centered and the motor dynamic brakes to rest.

The DB contactor and resistor may also be used for an armature shunt speed point. See page 11 and Fig. 8 on Page 21.

Class 2245 Reversing, Plugging,Dynamic Braking Controller (RPDB)

A Class 2245 circuit is shown in Fig. 6 Page 19. This circuit is a combination of the Class 2243 circuit and the Class 2244 circuit with relay AP omitted. Relay 3TR, a time delay relay, keeps the dynamic braking circuit open when the master switch is moved rapidly through the "OFF" position. If the master switch is moved to the stop position, DB will drop out and apply dynamic braking after 3TR drops out.

Fig. 6A shows the speed-torque characters of a compound wound motor with Class 2245 controller.

Controllers for Series Motors

A Class 2241 or a Class 2243 controller may be used with a series wound motor. These circuits are the same as those of Figs. 2 and 4 respectively, except that the shunt fields and discharge resistors are omitted. The speed-torque charcters are similar to those of Figs. 2A and 4A except that the slope of the curves is steeper. At no load, most series wound motors will exceed their maximum permissable speed. Other class controllers may be used with series wound motors but require special circuits and additional apparatus.

Controllers for Adjustable Speed Shunt Motors

Class 2240 controllers are also built for use with adjustable speed, shunt wound motors. Fig. 7 Page 20. Shows a typical circuit for a Class 2241 controller for such a motor. This circuit is similar to the circuit of Fig. 2 with the addition of the shunt field rheostat, resistors, and relays FA, FD, FL and FP.

Field relays are usually relays having two operating coils and their pick-up and drop-out are adjustable over a wide range. Each coil may either be a strap wound coil capable of carrying the armature current of the motor or a wire coil suitable for the control voltage or the motor field current.

Field Protective Relay (FP), when required inserts a resistance in series with the shunt field to reduce its heating when the motor is a standstill. This increased heating at standstill is due to the absence of ventilation from the internal fan on the motor armature. This relay is sometimes called field economizing relay.

Standard mill motors have fields which are continuously rated at standstill and therefore do not need FP Relay.

Field Loss Relay (FL) prevents operation of the controller, when the field current falls below a certain value, by opening the MR coil circuit, thus preventing dangerously high motor over speeds. NEMA standards require a field loss relay on all shunt and stablized shunt motors, and on mill type compound motors having 60% or more shunt field. Westinghouse mill compound motors have less than 60% shunt field (except in special cases), and therefore do not require field loss relays.

Field Accelerating and Full Field Relay (FA) is a field fluttering relay whose purpose is to keep the armature current from exceeding certain limits while the motor is accelerating above base speed due to field weakening. It accomplishes this by shorting out the field rheostat when the armature current gets too high, which strengthens the shunt field and limits the acceleration rate. The armature current starts to fall and FA contact opens which then weakens the field and the motor accelerates again. The cycle is repeated until the motor speed reaches the new rheostat setting. A second coil serves to pick up the relay below base speed and thus apply full field while accelerating.

Field Decelerating Relay (FD) is a field fluttering relay similar to FA except that it operates to limit armature current while the motor is decelerating due to increased field strength. This is accomplished by FD relay contact opening to insert resistance in the field circuit which weakens the field and limits the deceleration rate. The armature current starts to fall and FD contact recloses, which again streqthens the field and the motor again decelerates. The cycle is repeated until the motor speed reaches the new rheostat setting. A polarizing coil prevents FD from picking up on accelerating currents.

The circuit shown is a typical circuit, but there are many modifications and features which may be added to suit individual applications.

Fig. 7A shows the speed-torque characteristics of a variable speed shunt motor with Class 2241 controller.

FA and FD are not usually required unless the speed range by field weakening exceeds two to one.

Controllers for Constant Speed Shunt Motors

The field circuits for a Class 2240 controllers for a constant speed, shunt wound motor are similar to that of Fig. 7 except that relays FA, and FD are not required, nor are the field rheostat or the decelerating resistance.

Armature Shunt

Resistors in series with the armature reduce the motor speed in direction proportion to the voltage drop across the resistor. This drop is numerically equal to the product of the resistance and the armature current: therefore, on light loads (either motoring or overhauling), the resistance will have little or no effect on the speed.

However, if a second resistance is connected in shunt (or parallel) with the armature, sufficient current can be drawn by this "armature shunt" resistor to secure sufficient voltage drop in the series resistor to obtain the lower speed desired.

In practice, the series resistor is usually the starting resistor and the armature shunt resistor a part or all of the dynamic braking resistor.

Fig. 8 illustrates a Class 2244 Controller with the dynamic braking resistor and contactor being employed as an armature shunt resistor and contactor.

The description of operation is similar to the Class 2244 description on page 9, except that when the master switch is in position 1, the motor is connected in series with the starting resistance and in parallel with the dynamic braking resistor and is accelerating at a lower speed (curve a on Fig. 8A) which is approximately 15% speed (at full load).

Moving the master swithh to position 2, contactor DB is energized and the dynamic braking/armature shunt resistor is disconnected and the motor will accelerate to some intermediate speed.

With the master switch in position 3, the motor will accelerate to base speed.

Fig. 8A shows the speed-torque characteristic of compound wound motor controlled by a controller as shown in Fig. 8

A separate armature shunt contactor is sometimes used to secure two steps of armature shunting. This results in two steps of dynamic braking as will, bringing the motor to a faster stop. The AS contactor is connected to a "Tap" of the dynamic braking/armature shunt resistor.

Series Brake

Any Class 2240 controller may have a series brake connected in series with the motor series field provided the motor load is never less than 10 percent of full load. A series brake so used would set when the motor load dropped to less than ten percent, then release as the motor load picked up and motor speed dropped due to the setting of the brake. The brake would continue to set and release.

Shunt Brake

Any Class 2240 controller may have a shunt brake. The coil of the shunt brake is energized from the control bus by the normally open contact of a brake relay (BR).

Basic Controllers and Logic

All of the circuits discussed in Part Two and illustrated by schematics in Part Three consist of a BASIC CONTROLLER to which some form of control LOGIC has been added to help explain the operation.

Inputs to the BASIC CONTROLLERS consist of "P" (the positive control "bus") and "0", on the positive side and "RST" (reset), FWD (forward) etc. connected to relay and contactor coils. Control LOGIC consists of connecting relay, pushbutton, master switch etc. contacts between "P" or "0" and the various other inputs to produce the desired operation.

A reset circuit must be provided first between "P" and "RST" to pickup the Master Relay MR. This contact must only be closed in the stopped or off positions and is frequently (as in Fig. 8) a contact of the Master switch closed only in "OFF". If the master switch (in this case) is "OFF and none of the overload or field loss or other protective contacts in series with MR are open, MR will pickup and both close its main contact to energize the "0"BUS" and seal in the master switch contact. Note that any protective devices (such as oil pressure switches etc. or any emergency stop pushbuttons should be connected in series with the reset contact of the master switch but not sealed by the auxiliary contact of MR. The opening of the MR coil circuit will of course stop the drive and it will be necessary to "reset".

With the "0 BUS" energized, logic contacts can now be utilized to control the motor at any one of a number of "speed points". Closing a contact between "0" and "FWD" (or "REV") will cause reversing controllers to run forward at the lowest speed.

An additional circuit between "0" and "FIS" (FORWARD INTERMEDIATE SPEED)will cause the controller to increase to the next higher speed point.

Energizing 1AC and 2AC will in sequence pick up the ACCELLERATING CONTACTORS but only after the accellerating timers have timed out.

Where motor can be field weakened, an additional speed input is available as FW or FA (full field coil) where the Field Accellerating relay is used. Note that operation of the FA Full Field Coil is inverted as this coil must be de-energized to go to weak field speed.

Both FIS and RIS are provided so that independent forward and reverse limit switches may be used if required.

1AC is usually connected to DB (see Fig. 8) either direct or thru logic contact so that 1AC and 2AC will be de-energized if a slow down limit switch is operated.

Resistors

Each controller requires a STARTING RESISTOR and where applicable a DYNAMIC BRAKING, ARMATURE SHUNT OR PLUGGING RESISTOR in addition.

The type LG unit frame, punched stainless steel grid and is employed for all horsepower sizes except very small motors. The grids are unbreakable and are suitable for rugged duty even though they are light in weight and capable of dissipating large amounts of power.

A "unit frame" resistor is one in which all of the grids in a given frame are the same. A small number of different standard frames are available which are employed in combination if necessary to make a resistor for any application. This minimizes the number of spare resistors required.

For NEMA resistor classifications see ratings given in Part 1 Page 7.

Part Three

LIST OF ILLUSTRATIONS

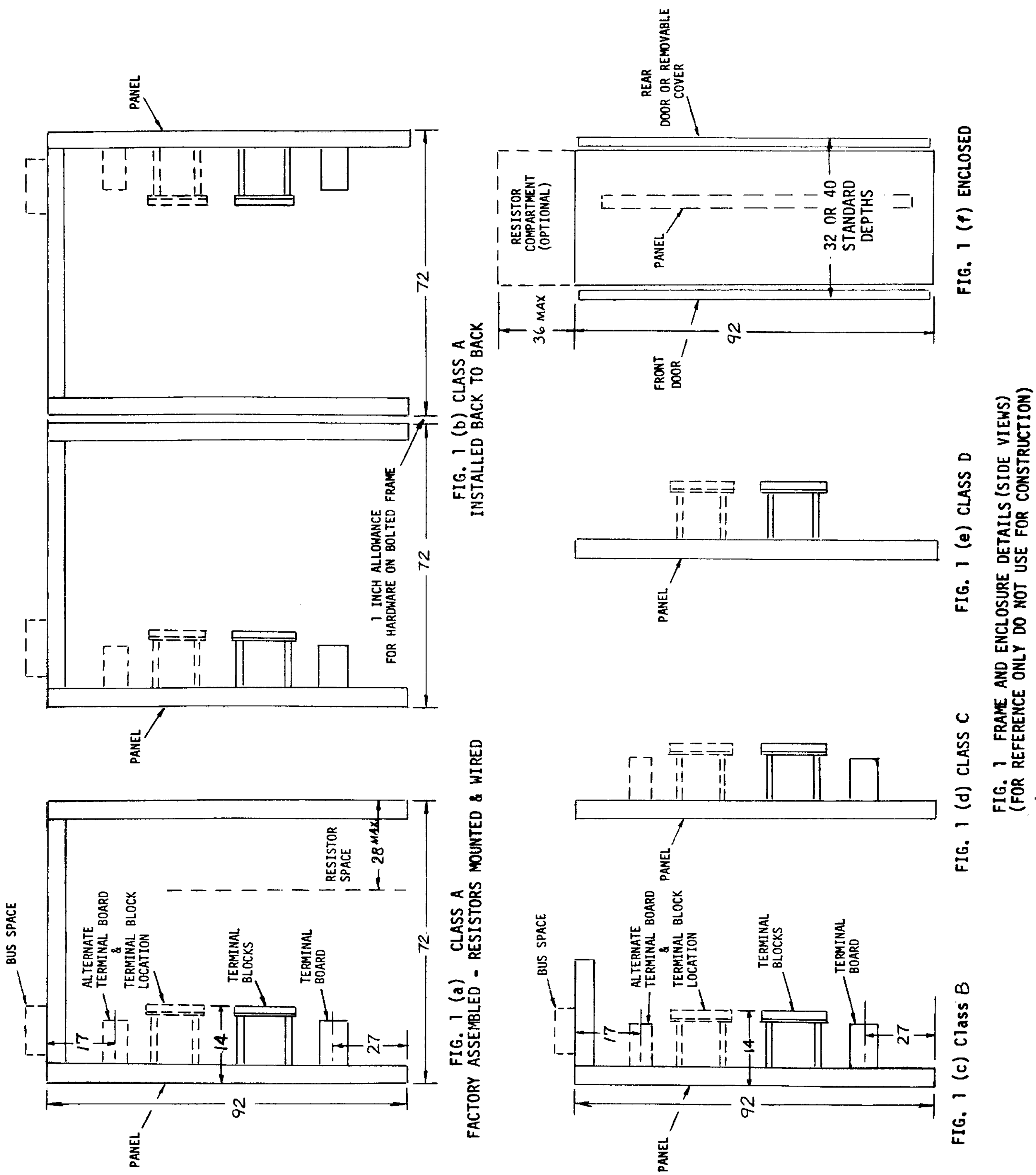


FIG. 1 (a) CLASS A
FACTORY ASSEMBLED - RESISTORS MOUNTED & WIRED

FIG. 1 (b) CLASS A
INSTALLED BACK TO BACK

FIG. 1 (c) Class B

FIG. 1 (d) CLASS C

FIG. 1 (e) CLASS D

FIG. 1 (f) ENCLOSED

FIG. 1 FRAME AND ENCLOSURE DETAILS (SIDE VIEWS)
(FOR REFERENCE ONLY DO NOT USE FOR CONSTRUCTION)

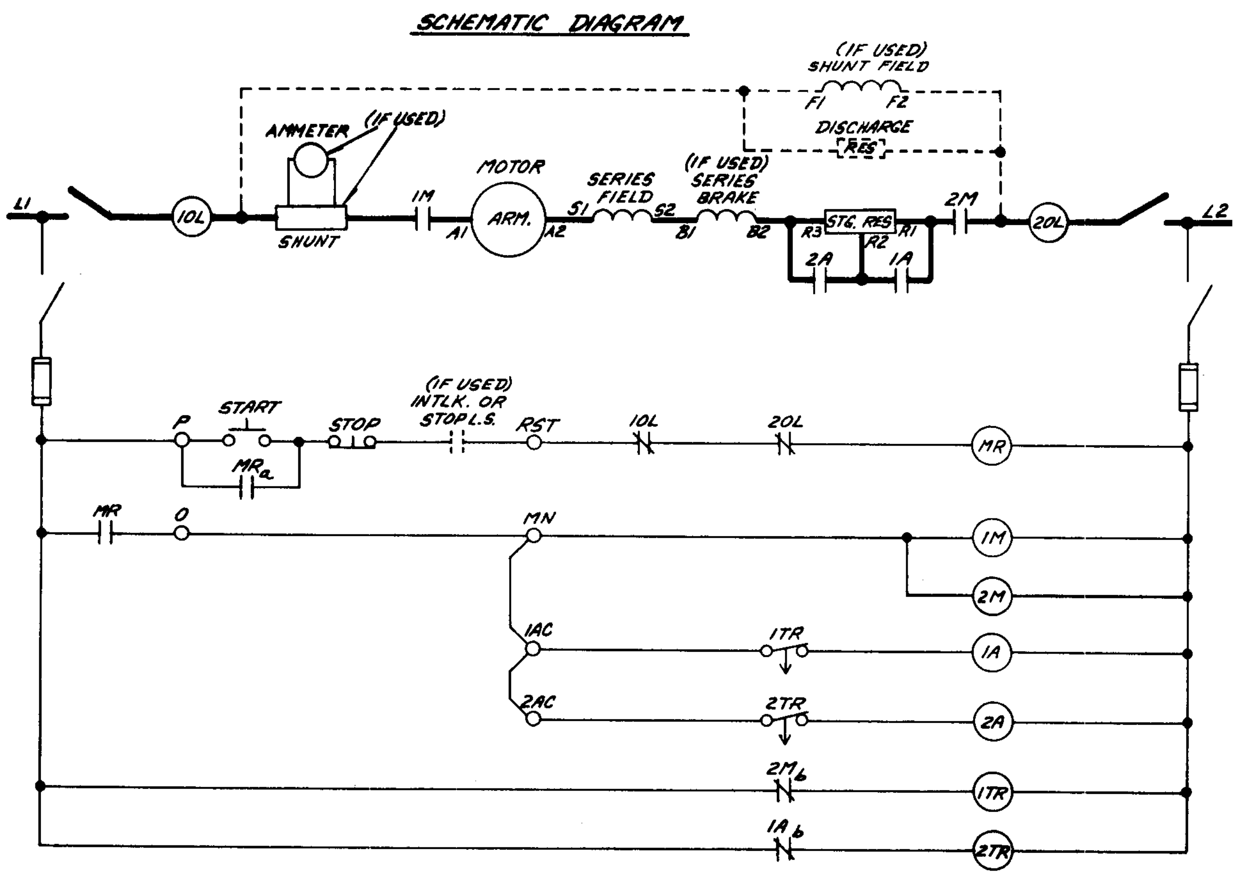
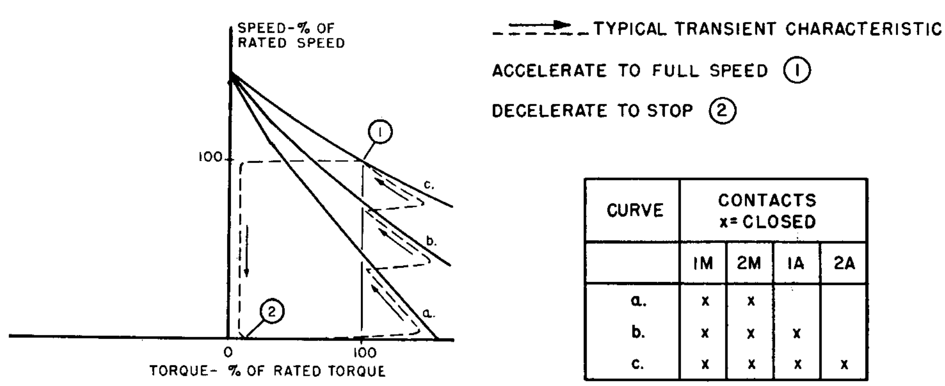


FIG. 2 Class 2241 Non-Reversing Controller (NR)



CURVE	CONTACTS x= CLOSED			
	1M	2M	1A	2A
a.	x	x		
b.	x	x	x	
c.	x	x	x	x

FIG. 2A Speed-Torque Characteristics of Compound Motor with Class 2241 Controller

SCHEMATIC DIAGRAM

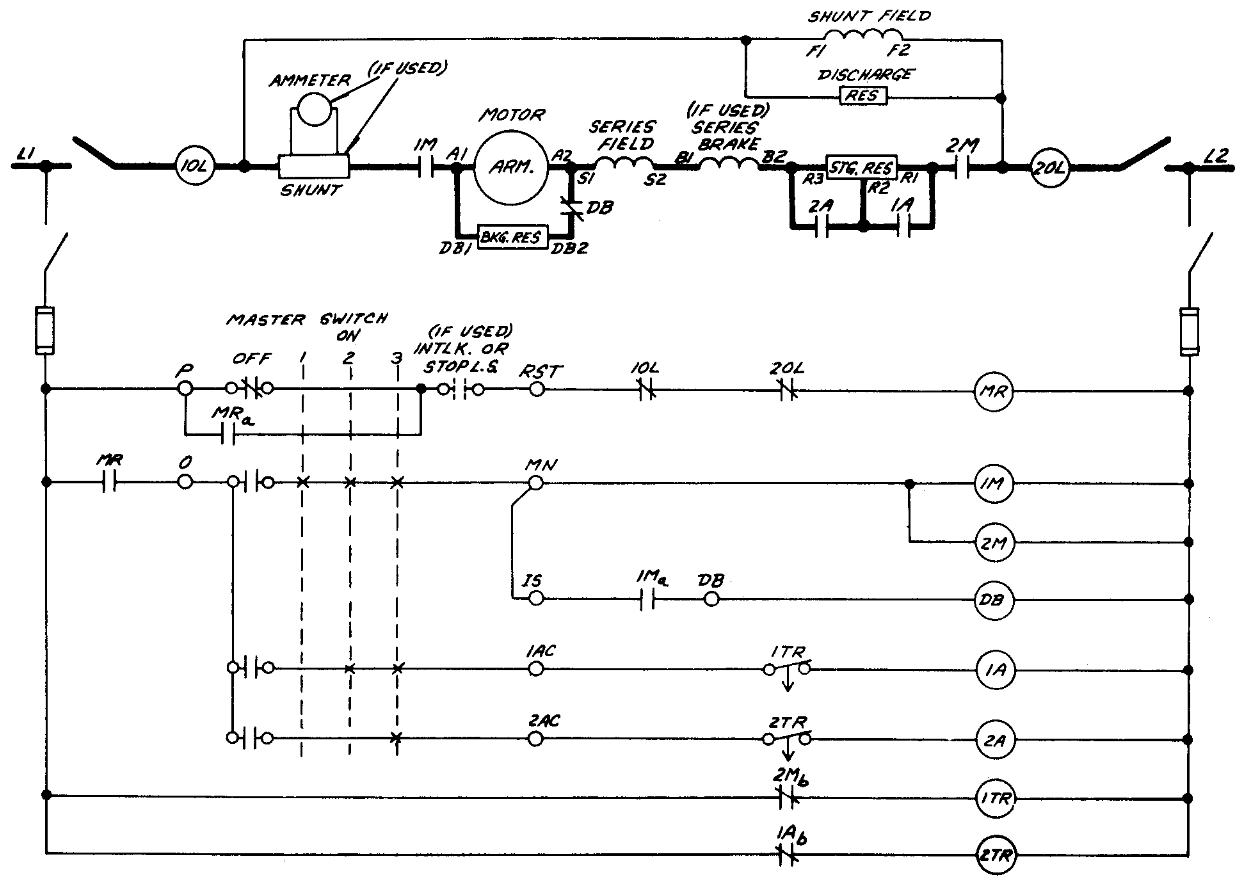
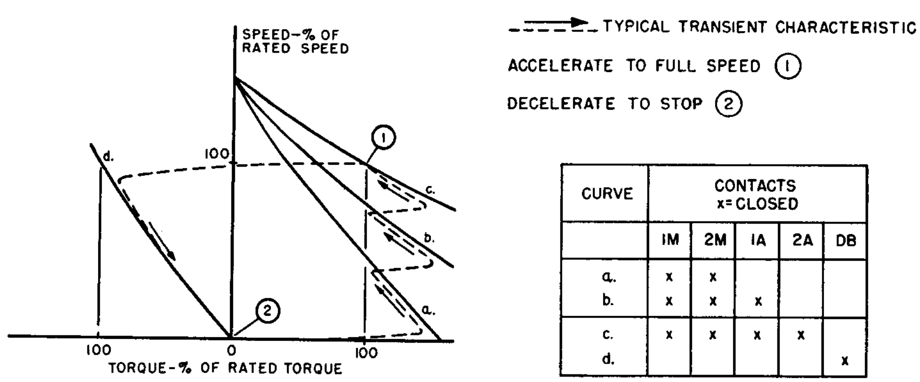


FIG. 3 Class 2242 Non-Reversing, Dynamic Braking Controller (NRDB)



CURVE	CONTACTS x= CLOSED				
	IM	2M	IA	2A	DB
a.	x	x			
b.	x	x	x		
c.	x	x	x	x	
d.					x

FIG. 3A Speed-Torque Characteristics of Compound Motor with Class 2242 Controller

SCHEMATIC DIAGRAM

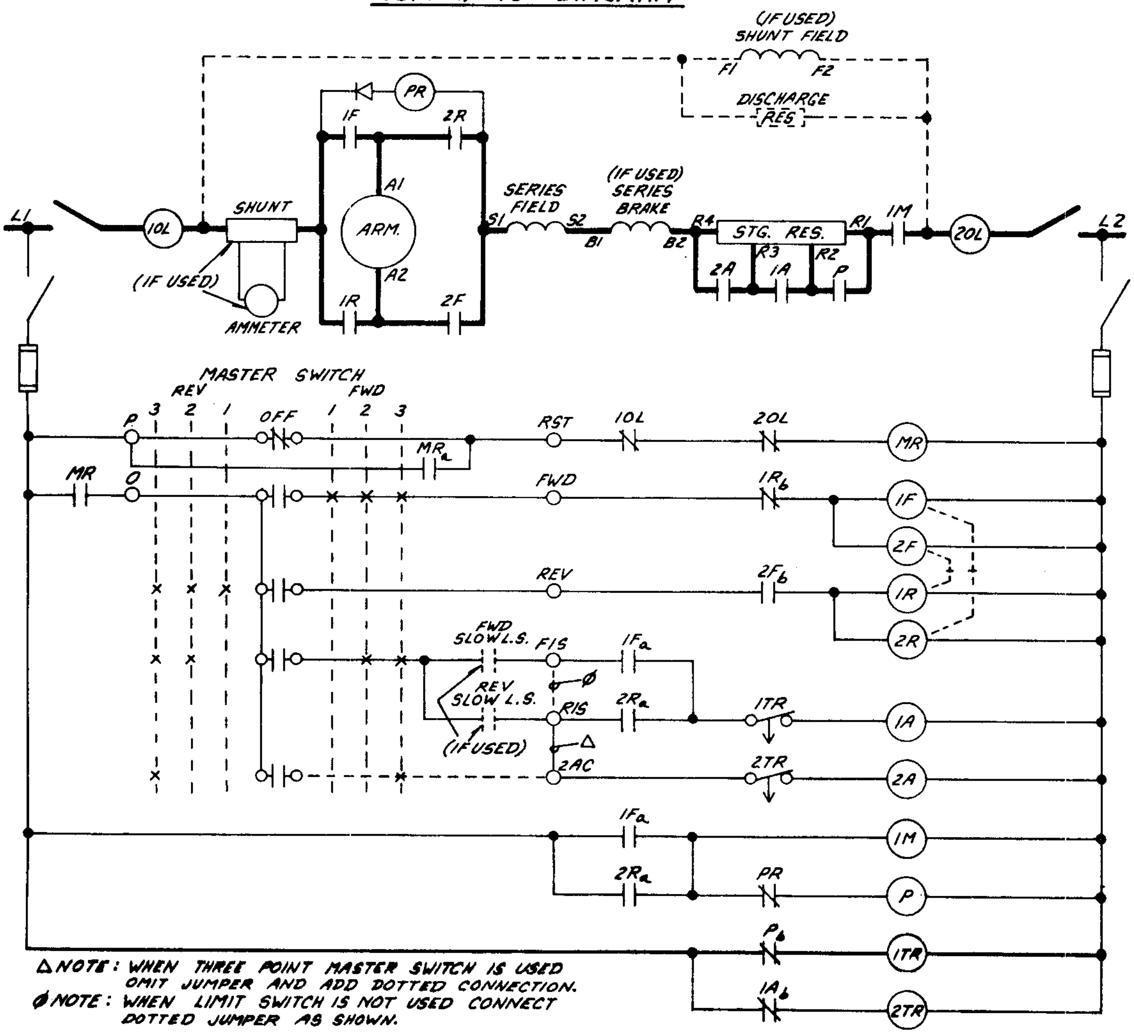
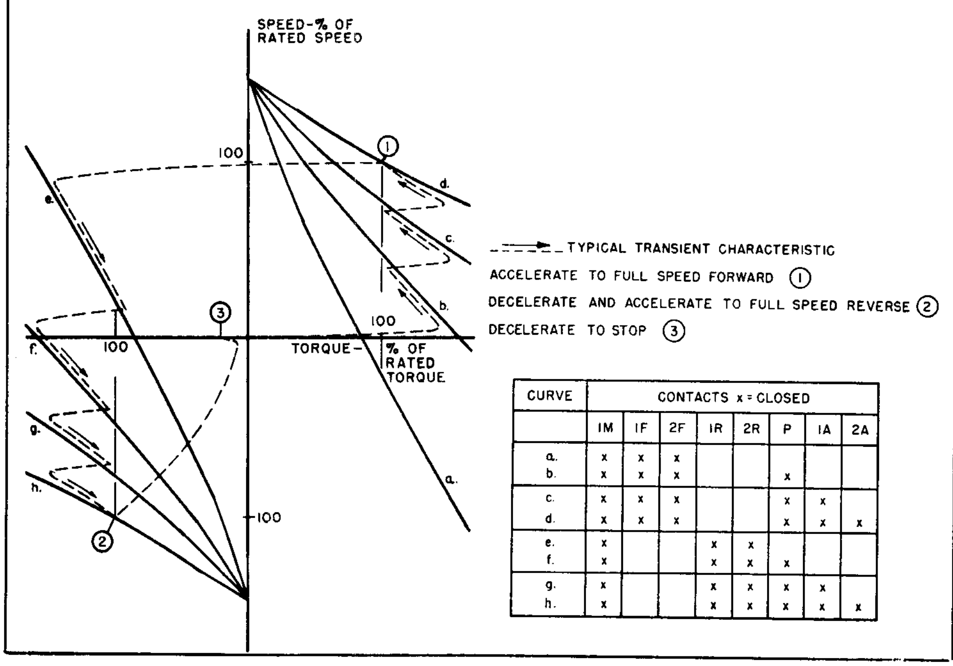


FIG. 4 Class 2243 Reversing, Plugging Controller (RP)



CURVE	CONTACTS x = CLOSED							
	1M	1F	2F	1R	2R	P	1A	2A
a.	x	x	x					
b.	x	x	x			x		
c.	x	x	x			x	x	
d.	x	x	x			x	x	x
e.	x			x	x			
f.	x			x	x	x		
g.	x			x	x	x	x	
h.	x			x	x	x	x	x

FIG. 4A Speed-Torque Characteristics of Compound Motor with Class 2243 Controller

SCHEMATIC DIAGRAM

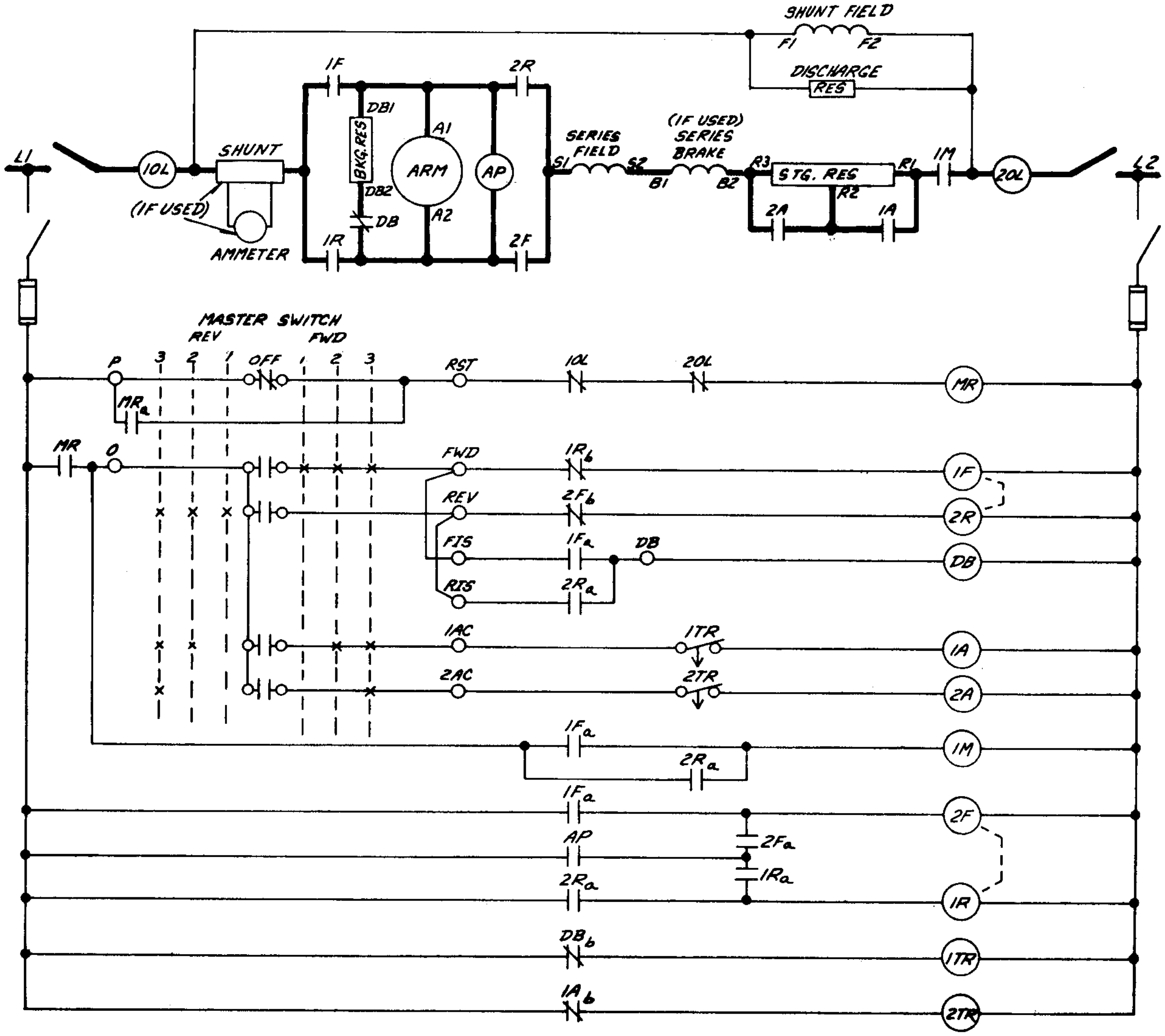
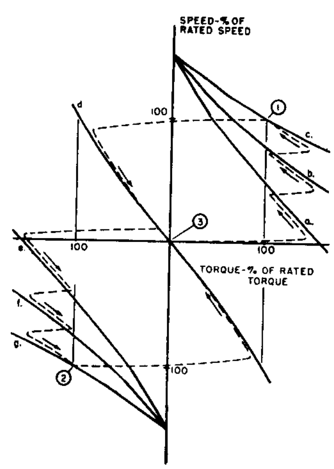


FIG. 5 Class 2244 Reversing Dynamic Braking Controller (RDB)



- - - -► TYPICAL TRANSIENT CHARACTERISTIC

ACCELERATE TO FULL SPEED FORWARD (1)

DECELERATE AND ACCELERATE TO FULL SPEED REVERSE (2)

DECELERATE TO STOP (3)

CURVE	CONTACTS x = CLOSED							
	IM	IF	2F	IR	2R	IA	2A	DB
a.	x	x	x					
b.	x	x	x			x		
c.	x	x	x			x	x	
d.								x
e.	x			x	x			
f	x			x	x	x		
g.	x			x	x	x	x	

FIG. 5A Speed-Torque Characteristics of Compound Motor with Class 2244 Controller

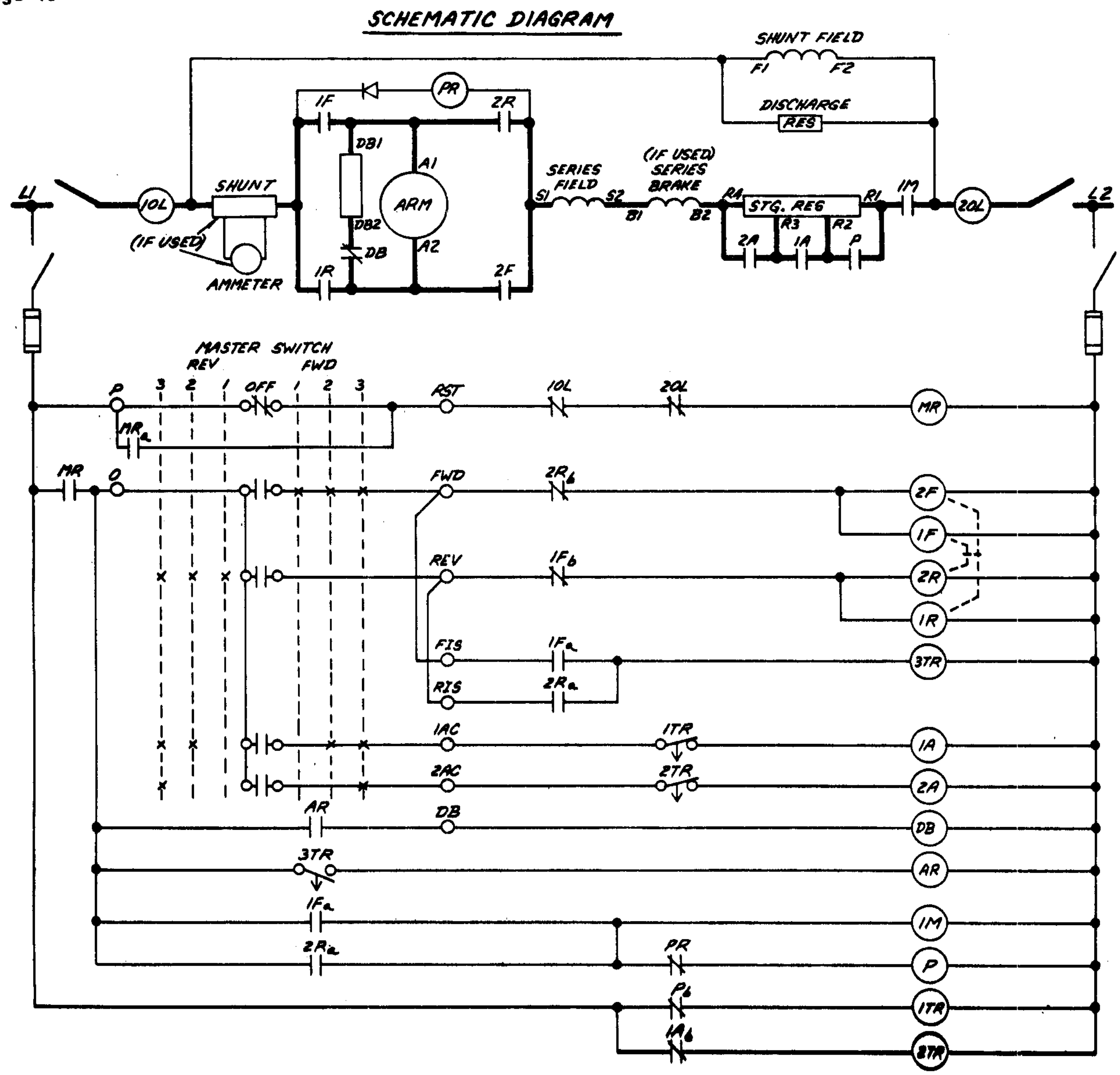
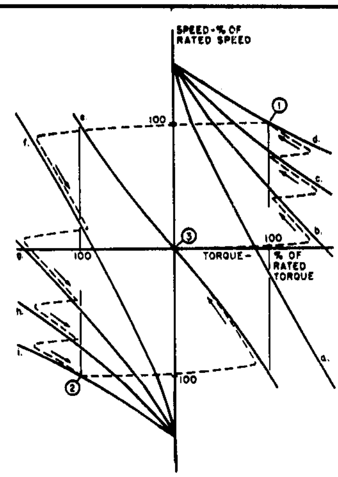


FIG. 6 Class 2245 Reversing, Dynamic Braking, Plugging Controller (RPDB)



- - - -▶ TYPICAL TRANSIENT CHARACTERISTIC

ACCELERATE TO FULL SPEED FORWARD (1)

DECELERATE AND ACCELERATE TO FULL SPEED REVERSE (2)

DECELERATE TO STOP (3)

CURVE	CONTACTS x = CLOSED								
	IM	IF	2F	IR	2R	P	IA	2A	DB
a.	x	x	x						
b.	x	x	x			x			
c.	x	x	x			x	x		
d.	x	x	x			x	x	x	
e.									x
f.	x			x	x				
g.	x			x	x	x			
h.	x			x	x	x	x		
i.	x			x	x	x	x	x	

Fig. 6A Speed-Troque Characteristics of Compound Motor with Class 2245 Controller

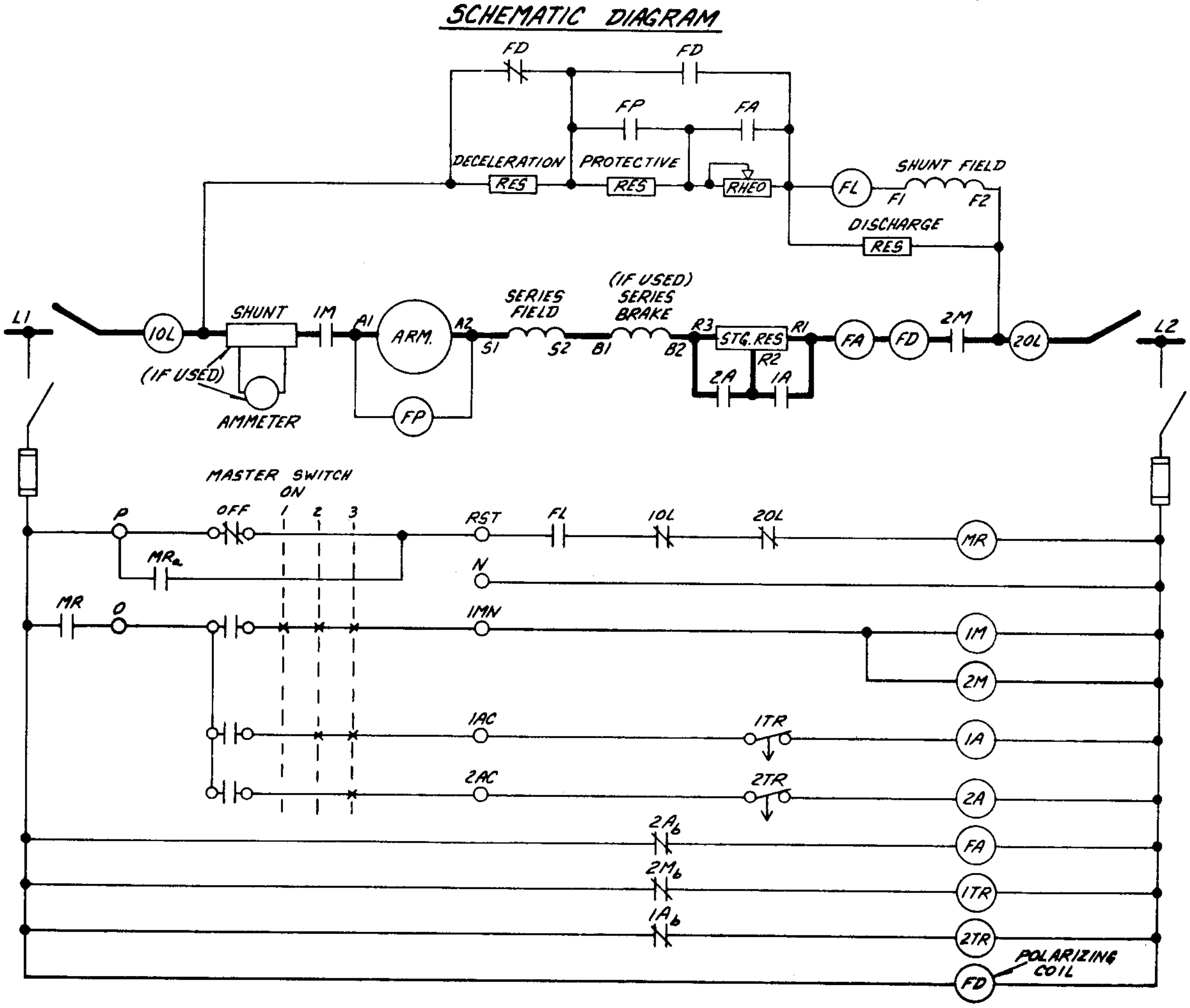
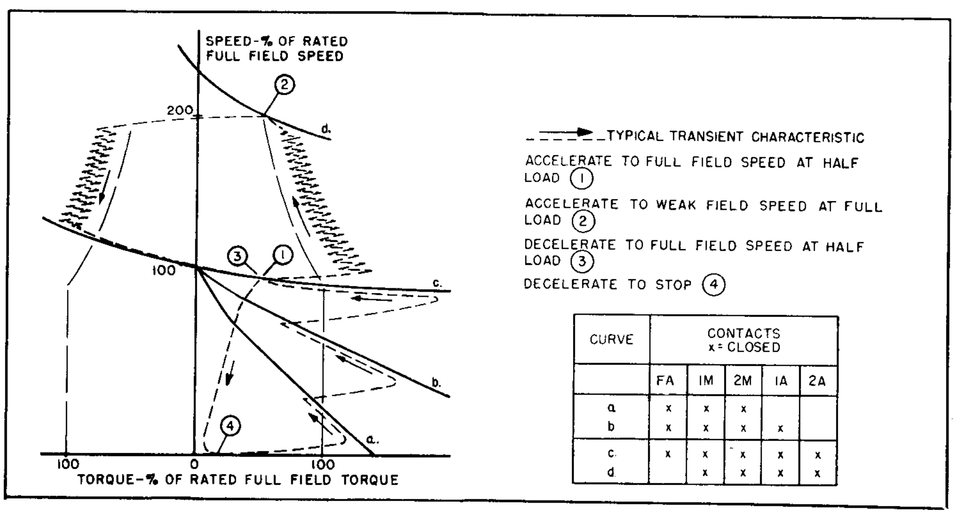


FIG. 7 Class 2241 Non-Reversing Controller Adjustable Speed Controller (NR)



CURVE	CONTACTS x = CLOSED				
	FA	IM	2M	IA	2A
a	x	x	x		
b	x	x	x	x	
c	x	x	x	x	x
d		x	x	x	x

FIG. 7A Speed-Torque Characteristics of Adjustable Speed Shunt Motor with Class 2241 Controller

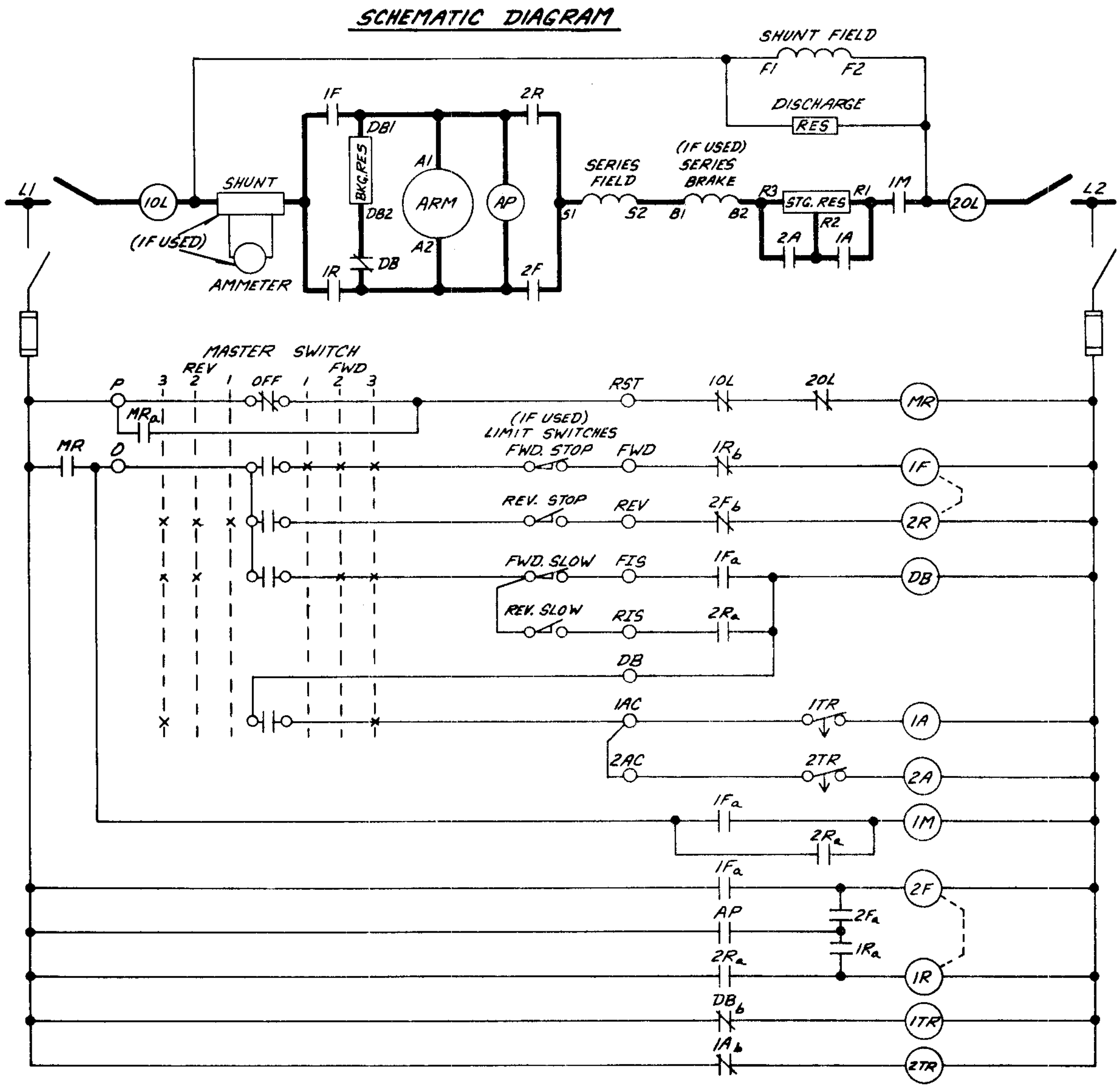
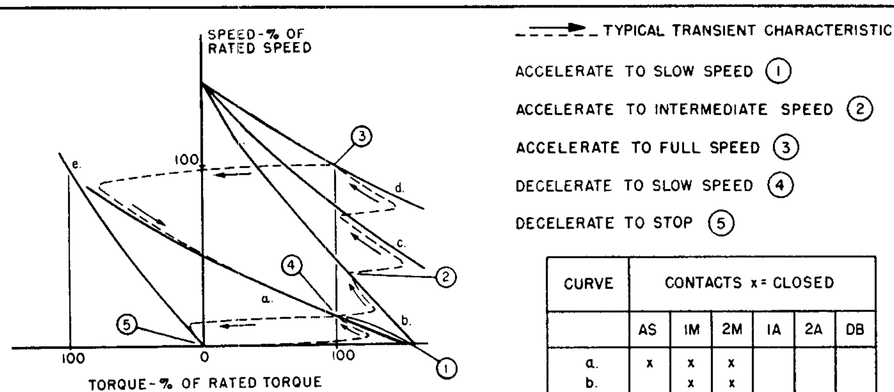


FIG. 8 Class 2244 Reversing, Dynamic Braking Controller (RDB)
With Dynamic Braking Resistor used as Armature Shunt



CURVE	CONTACTS x = CLOSED					
	AS	1M	2M	1A	2A	DB
a.	x	x	x			
b.		x	x			
c.		x	x	x		
d.		x	x	x	x	
e.						x

FIG. 8A Speed-Torque Characteristics of Compound Motor with Controller as shown in Fig. 8

Part Four INSTALLATION AND OPERATION

Location

The location of the controller should provide protection, accessibility, and ventilation. The controller should be located as near the controlled machine as possible and preferably in sight of the operator. The master switch should be in sight of the controlled machine.

Open control panels and panels with general purpose enclosures should be located in a clean dry atmosphere. Various kinds of atmospheric contamination are permissible for special enclosures as indicated by the NEMA names for these enclosures - dust-tight, dustproof, watertight, etc. Particular care should be taken during installation in a building still under construction to protect the controller against dust,dirt, and falling objects. The degree of protection provided against injurious elements, such as dust, water, oil, or acid, will to a large extent determine the life and dependability of the controller.

Accessibility requirements for connecting and servicing controllers vary for different designs. Check the outline drawing carefully to determine the minimum space requirements. Allow space for a service man to stand, to use tools, to remove arc boxes, and to open hinged cabinet doors.

Open control panels should have an ambient temperature of 40°C or less. Enclosed controllers should have an ambient temperature less than 30°C. Locate ventilated enclosures so that walls and other structures do not obstruct the ventilation openings. Provide a flow of air for controllers which dissipate a large amount of heat - such as resistance starters for motors which reverse frequently.

Foundation

Foundations for floor mounted controllers should be level. Supports for wall mounted controllers should be vertical. Foundations and supports should be free of excessive vibration.

The foundations should include conduits or other means for connecting the controller to the controlled machine, master switch, and other devices. Check the outline drawing to determine the location at which conduits may enter the controller. Check the external connection diagram to determine the number of conduits and their termini. Check the National Electric Code or other applicable code to determine the conduit size for the required number of conductors of the required size. Ground all conduits.

Mounting

Set the controller in place, level it, and secure it by means of imbedded bolts, through bolts or other suitable hardware.

If desired, adjacent separate controllers or shipping sections may be bolted together through holes provided in the side of tha panel and/or the frame. Controllers having factory assembled bus usually has bus extending the length of the shipping section and "splice" plates are provided to connect to the bus in the adjoining section. The "splice" plates aar bolted to the frame for shipment and should be placed beneath the bus clamps on either side of the split and the clamps tightened. Bolts should also be installed in any holes provided.

It is recommended that the panel of each steel panel type controller be grounded.

Connection

Connect the apparatus according to the external connection diagram. If this diagram specifies a maximum allowable resistance for any particular set of connections, choose a wire size which will keep the resistance of these connections below the limit. For the connections between a d-c ammeter shunt and a remotely mounted ammeter, choose a wire size which will give the lead resistance specified on the dial of the ammeter. A remotely mounted ammeter may have a calibrating resistor to compensate for insufficient lead resistance, In this case choose an oversize wire and adjust the calibrating resistor to obtain the correct lead resistance. choose all other wire sizes from the National Electric Code or other applicable code.

Wires can be pulled through conduits most successfully if all the wires in any one conduit are the same size. Therefore, armature circuit connections and shunt field circuit connections should usually be in separate conduits.

Place both wires of a single phase a-c circuit in a single conduit. Place all wires of a polyphase a-c circuit in a single conduit.

Preparation

Open the circuit to the power supply, Remove blocks and ties from all contactors, relays, instruments, and other devices. With a clean dry rag, clean throughly the contact surfaces and magnet gap surfaces of all contactors and relays. The gap surfaces of some a-c magnets are coated at the factory with a film of petrolatum to inhibit rusting in storage. Remove this film to prevent the magnet from collecting dust. Tighten any hardware which may have worked loose during shipment.

Check the controller nameplate to be sure the controller rating agrees with the motor rating and the power supply.

Operate all contactors and relays manually to be sure that they are free of friction, that the contact surfaces seat properly, and that the various springs work properly. Check mechanical interlocks to be sure they prevent the contacts of one contactor from touching when the other contactor is closed. Release the brake manually and rotate the motor manually to be sure that they are free of friction and free of foreign matter.

Tests Preliminary

Open the circuit from the controller to the controlled machine. Close the circuit from the power supply to the controller. Operate the master switch and other pilot devices. Check the sequence of relay and contactor operation. This sequence has been checked at the factory. An additional check will call attention to any faulty external connections or to any faulty external connections or to any damage that may have been done during shipment. Open the circuit to the power supply, and reclose the circuit to the controlled machine.

Close the circuit to the power supply. If a motor controller has separate switches for the power circuit and for the control circuit, always close the power circuit switch first and the control circuit switch last; this sequence will prevent picking up the contactors and then line-starting the motor with the power switch.

Tests-Operational

Before the motor is started, provision should be made to insure that the motor will operate at slow speeds for the initial operations until the controller and limit switch adjustments can be made and to be sure that the electrical and mechanical portions of the drive are in correct operating condition. This will avoid hazard to equipment or personnel.

Field rheostats or resistors should be set at minimum resistance and any field weakening or full field relays blocked temporarily to apply only full field to the motor. Since the first operation of the motor should be with the entire starting resistance in series with the motor armature, 1A and 2A should be prevented from picking up by blocking 1TR and 2TR open if this can not be accomplished by the master switch.

The operator should also be prepared to stop the motor quickly if the direction is incorrect, the armature current is excessive, the speed is too high or there is any other indication of electrical or mechanical trouble.

If the limit switch is required to stop the drive at a critical position, make the following tests away from the critical position if possible. If not, set the limit switches as described later before proceeding.

Check the polaritites of the shunt and series fields by first jogging the motor with and without the shunt field connected and observing the direction of rotation in each case. If the direction is the same, the relative polarities are correct. Mill type compound motors having approximately 50 percent series and 50 percent shunt field should have the series field temporarily shorted when the shunt field is connected in order to check the polarities.

Also observe the relationship between the drive movement and the master switch. If this is incorrect reverse the motor armature connections A1 and A2 (do not change internal connections of the motor).

Remove the blocking on relays 1TR and 2TR (if it was used) to permit 1A and 2A to pick-up. Observe the current peaks during acceleration from rest to base speed. Usually the starting resistor is designed to limit the current on starting to 150 percent of full load (NEMA resistor classes 153P, 155, 163P & 165). If the starting resistance is correct, the first peak should not exceed 150 percent.

On a controller with two accelerating contactors, the three peaks corresponding to the three steps (1A and 2A both open, 1A closed and 2A open & 1A and 2A both closed) should be approximately equal with full load on the motor. This indicates that the motor speed is correct when 1A and 2A close so that the Back E.M.F. is high enough to limit the current. If the second peak is higher than the first, it indicates that the motor needs more time to accelerate on the first step and that 1TR should be set for a longer time. Conversely if the second peak is lower, the time on 1TR should be decreased. The thrid peak should be compared with the second and relay 2TR adjusted in a similar manner.

If the controller has relays FA and FD, check the coil polarities as follows: Remove the blocking on full field or field weakening relays and set the field rheostat or resistor for the motor top speed. Accelerate and decelerate the motor from base speed to weak field speed. Check to see that FD does not pick up during acceleration and that it flutters during deceleration. Check FA to see that it flutters during acceleration. This test should be made in several steps from base to the highest speed. Relays FA and FD are set in the factory to pick up at 150 percent and drop out at 120 percent of full load (approximately).

Lever, cam or travelling nut limit switches should be adjusted to provide slow down and stop and any other function required. Try the limit switches by hand (lever type) and at slow speeds (all switcnes) to make sure the correct contacts are used and the switches are wired correctly. Make sure the mechanical equipment (such as gearing on the cam limit switches and the arm or shoe which operates the lever switches) will operate the limit switch correctly. If hatchway type lever limit switches are used for slowdown, make sure that the switch is not released by the mechanism before the stop is reached or the motor will speed up again. Also check to make sure the slowdown is initiated sufficiently ahead of the stop point to allow time for the drive to slow down before the stop is initiated even with the heaviest load at top speed. Make sure that armature shunt slowdown is used if the load can be light or is overhauling.

Check the blowouts on all type AV relays used in the field circuit to make sure the arc is blown upward. If not, reverse the blow out magnets.

Part Five MAINTENANCE

Equipment well cared for will provide satisfactory and dependable operation with a minimum of trouble. It cannot, therefore, be too strongly emphasized that good maintenance will prove to be a profitable and highly important factor in satisfactory controller operation.

All possible safety precautions should be taken before working on electrical apparatus, and only skilled personnel should service the electrical equipment.

Minimum controller maintenance will be required if the equipment is located in the most favorable of all possible locations as outlined in the installation and operation instructions, Part Four of this book. A plan should also be worked out and put into practice whereby the controller equipment is provided with a periodic and systematic inspection. This type of preventative maintenance will often avoid expensive replacement of complete apparatus under breakdown concitions.

Suggestions for the maintenance of each type of relay contactor, and switch are given in the corresponding instruction leaflets.

Preventative maintenance by means of periodic inspection and servicing should include the items covered in the following paragraphs.

Cleaning

Thoroughly clean all dust from the apparatus, preferable by blowing it out with compressed air. In the absence of an air supply, clean the equipment by brush or by any other acceptable method. It should be noted that oily rags or waste should not be used as they will leave an oil film on the equipment which will collect dust particles.

Lubrication

Except for special equipment, controllers require no lubrication. This is especially true of contactors and relays. In the few cases where lubrication is desirable such as on built-in rotating machines, bearings for large master switches, etc., it should be used sparingly and great care should be used in applying it. The use of oil on contactors and relays will cause dirt to collect in the bearings and moving parts, and may cause operating difficulties because of increased fricition. A-C magnet faces may have a thin film of light oil to prevent rusting.

Mechanical Inspection

Moving parts should be checked and operated where possible in an effort to locate loose pins, bolts, and weak springs; and to locate parts which are developing excessive friction and are becoming hard to operate. Parts subjected to the greatest wear should replaced when the wear has become excessive.

Contacts

Current-carrying contacts should be inspected for wear and for signs of excessive heating. Deeply pitted and burned contacts, as well as those worn thin, should be replaced with new ones. When making replacements, it is desirable to replace contacts in pairs rather than to install a new contact to operate with one that is partly worn. In general the condition of a contact should be judged from its shape and the condition of its contact-making surface, bearing in mind that contact surfaces need not be entirely smooth. A slightly roughed surface, if clean, is entirely satisfactory. Contact color is not necessarily an indication of condition as the color is often due to oxidation of the contact material. A dark copper contact may have an undesirable high contact resistance due to the formation of copper oxide and it would be wise to clean it, whereas, a dark silver contact still has low contact resistance and need not be cleaned.

When replacements are made, surfaces for seating the new contacts should be clean. Contacts which are burned, but not badly, may be cleaned with a fine file. Do not use emery cloth or sandpaper as abrasive granules may become imbedded in the contact surface. The use of a file should be avoided where possible, and when it is used, care should be taken to maintain the shape of the contact. Replacements must be tightly secured, as a loose contact will soon overheat.

Arc shields, when removed for the inspection or replacement of contacts, must be fixed firmly in their proper position after the replacement or inspection is completed. Otherwise, they will not function as effectively in interrupting currents flowing through the contactor.

Springs

In connection with maintenance, springs (and especially contact springs) are often overlooked. Weak springs may cause bouncing contacts and in many cases is the chief cause of frozen or welded contacts; and they are also a contributing cause of overheating resulting from low contact pressure. It is important, therefore, that springs be systematically checked for signs of deterioration. There are two methods which may be used; one is by comparison with new springs of the same design; and the second is by measuring contact pressures for comparison with recommended values of the manufacturer.

By comparison with a new spring as to size, shape and tension, it is readily possible to determine when a spring has been so overstressed or overheated as to have lost its efficiency. This comparison cannot be expected to indicate minor deficiencies or small reductions in tension.

Where there is any doubt concerning the condition of the spring, or where there is evidence of overheating, the contact pressure should be measured as noted in the following paragraph.

To measure the contact pressure, a spring scale should be attached to the moving contact at, or near, the point where it touches the stationary contact. A thin piece of paper is then placed between the contacts and the contactor is mechanically closed. A pull is then exerted on the moving contact through the scales in a direction vertical to the contact surface, so that the line of pull projects through the center of this surface. The contact pressure is then the measure in pounds required to separate the contact sufficiently to permit the paper to be removed from between them.

When a spring is proven inefficient, it should be immediately replaced, and spring washers should be added or taken out as required to provide the recommended contact pressure. For recommended contact pressures, refer to the instruction leaflets included for the various contactors used.

Loose Connections

As loose connections are an evasive an annoying source of trouble, they should be checked-especially on those applications subject to changing temperatures and vibration. As many connections as possible should be checked, and it is especially important that connections to external leads be tightly made.

Replacing Parts

The replacement of defective coils requires that coil leads be disconnected. In instances of this kind, and especially where multiple coils are used, it is important that the connections to the replacement coil be the same as to the original coil. Otherwise, relative polarities may be changed and the device may become inoperative. Similarly, other replacements involving connections should be made to provide the same circuits as on the original equipment.

It should be kept constantly in mind that any change or replacement should improve the operation of the control and associated motor-driven equipment. Replacements, if carelessly made, may result in less dependable operation than existed before they were made.

Shunts

Flexible shunts of fine stranded copper must be tightly connected and must not have broken strands. Broken strands increase the current on the remaining strands and cause overheating.

Maintenance Checks

Preventative maintenance will prove well worth while, yet there will be occasions when contactors or relays fail to function properly. Then this occurs, a check should be made for the following causes which are amoung the more common reasons for such failures:

A. Failure to close may be caused by:

   1. Disconnected power supply or voltage too low.
   2. Loose or broken connection to the operating coil.
   3. The operating coil may be open or short circuited.
   4. There may be mechanical friction or interference between parts which may prevent it from closing.

B. Failure to open may be caused by:

   1. Mechanical interference between parts.
   2. Contact tips may have welded together due to overheating.
   3. Residual magnetism may be holding magnet because of low kickout spring pressure.

Table No. 2. DEVICE TYPE AND SUPPLEMENTARY PUBLICATIONS

DEVICE AND TYPE	PUBLICATION	APPLICATION
Contactor (M and MD)		
Frames 310,410,510,610,710	I.L. 15-800-2	Line, Accelerating, Reversing, Plugging and Armature Shunting Contactors.
Frames 810,910	I.L. 15-800-3	
Frames 301,401,501,601,701	I.L. 15-800-1	
Contactor or Relay (M and MD) 50 ampere frame		
Frames 010,110,210	I.L. 15-800-M010/110/210-1	
Frames 011,111,211	I.L. 15-800-M011/111/211-1	Master Relay (MR) and Control Relays,
Frames 020,120,220	I.L. 15-800-M020/120/220-1	Field Relays (High Current Fields)
Frames 021,121,221	I.L. 15-800-M021/121/221-1	Shunt Brake and Clutch Relays,
Frames 022,122,222	I.L. 15-800-M022/122/222-1	Solenoid Control
Frames 001,101,201	I.L. 15-800-M001/101/201-1	
Electrical Interlock		
L46	I.L. 15-829-L46-1	Int. for 50 Amp M Contactor
L62	I.L. 15-829-3	Int. for M301, 401 etc.
L64	I.L. 15-829-7	Int. for M310, 410 etc.
Relays		
AV	I.L. 15-827-11	Dual Coil Field and Adjustable Voltage and/or current Relay (FA,FD,FL,AR,PR, etc.
AYV	I.L. 15-827-6-AYV	Anti-Plugging Relay (AP)
Agastat Relay	SR-15X	Timing Relay (1TR,2TR, etc.)
TI-2	I.L. 3487	Overload Relay (1OL,2OL, etc.)
Ammeter Shunt		
G	I.L. 43-850-A	50 Millivolt
Brakes		
TM	I.L. 5204-1	Shunt or Series
Resistors		
Unit Frame	Application Data 14-990	
LG (Steel Grid)	I.L. 16-600-1	